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The Orbit of Flora; with Corrections to Brünnow's "Tafeln der Flora." By A. M. W. Downing, M.A.

The tabular places of *Flora* as given in the *Berliner Jahrbuch*, which are derived from Brünnow's Tables, are, and have been for several years past, considerably in error. With the view of obtaining an orbit from which more accurate places may be deduced, I have undertaken a discussion of the meridian observations of the planet made during the years 1865–1888 inclusive, and I now beg leave to communicate the results of this investigation to the Society.

The observations discussed are principally those made at Greenwich and at Paris. In cases where these are not sufficiently numerous I have availed myself of the results obtained at Hamburg (1881), Leiden (1870, 1872), and Washington (1872, 1879, 1883). These various series of observations have been reduced to a uniform system in the manner explained (in the case of observations of *Juno*) in *Monthly Notices*, vol. l. pp. 487–489. For the Paris observations, and for the Greenwich observations of R.A., the corrections adopted are those given on the pages referred to. To the Greenwich observations of declination the following corrections (corresponding to those given on p. 488 of vol. l.) have been applied:—

Year.	Dec.	Corr.	Year.	Dec.	Corr.
	°	"		°	"
1865	+10	−0·7	1873	+ 2	−1·0
1866	−21	−2·0	1875	+ 2	−1·0
1868	+20	−0·7	1876	−18	−1·6
1869	−17	−1·8	1879	−21	−0·6
1871	+21	−0·7	1881	+22	−0·1
1872	− 8	−1·3	1882	−16	−0·2

The later Greenwich observations require no correction.

The Hamburg observations of 1881 require a correction in R.A. of $-0^{s}\cdot02$.

The Leiden observations require corrections in—

	R.A.	Dec.
	s	"
1870	−0·04	−0·4
1872	−0·01	+0·1

The Washington observations require corrections in—

	R.A.	Dec.
	s	"
1872	−0·03	−0·2
1879	−0·05	+0·6
1883	−0·02	+0·4

My thanks are due to Professors Rümker and Bakhuyzen for their courtesy in giving me the necessary information as to the mode of reduction of the Hamburg and Leiden observations respectively. The corrections to the Washington observations have been deduced from a consideration of the published statements regarding their mode of reduction.

These corrections having been applied, the following errors of the Tables were formed for the mean date of the observations made near the time of each opposition of *Flora*, by plotting down the observed errors on each day of observation, and drawing a curve through the points thus obtained:—

Date.	Δα.	Δδ.
	s	"
1865 Mar. 21	− 2·51	+13·3
1866 July 11	− 3·72	+ 1·1
1868 Feb. 22	− 3·94	+10·2
1869 June 8	− 4·60	+14·1
1870 Dec. 29	− 6·28	− 9·0
1872 May 15	− 5·54	+28·5
1873 Nov. 8	− 8·07	−45·1
1875 Apr. 17	− 6·62	+41·7
1876 Aug. 24	−12·05	−46·8
1879 July 5	−11·20	+ 6·4
1881 Feb. 13	−10·76	+21·9
1882 June 9	− 9·42	+40·6
1883 Dec. 4	−12·75	−30·2
1885 May 12	− 8·90	+53·9
1886 Oct. 29	− 9·93	−58·4
1888 Apr. 12	− 8·76	+51·5

The equations connecting the variations of the elements of the orbit with the above errors were then formed in the usual manner, the adopted weights being simply the number of observations on which each absolute term in the equations depends.

The equations of condition for determining the required corrections to the elements are the following (where $dm = 1000\, d\mu$):—

Equations deduced from Right Ascensions.

								Weights.	Residuals.
1	$+0.19363 d\pi$	$-8.59260 d\Omega$	$+9.74826 di$	$+0.23185 d\phi$	$+0.09086 dM$	$-0.71169 dm$	$-37''.1 = 0$	8	$+24''.5$
2	+0.26416	−8.40637	+7.78746	−0.55926	+0.25880	−0.82588	− 51.9 = 0	6	+26.7
3	+0.22562	−8.64058	+9.38987	+0.48945	+0.19229	−0.68605	− 55.4 = 0	7	+14.0
4	+0.22913	+8.22115	+9.20839	−0.35740	+0.14233	−0.56291	− 65.8 = 0	6	+21.2
5	+0.29015	−7.56703	+8.10823	+0.57022	+0.36103	−0.67575	− 88.1 = 0	10	− 2.4
6	+0.19321	+8.25696	+9.65087	−9.87313	+0.06658	−0.26269	− 82.2 = 0	7	+ 6.0
7	+0.29027	+8.18752	+9.83821	+9.55908	+0.43192	−0.46367	−121.0 = 0	12	−15.6
8	+0.18068	−7.86629	+9.78672	+9.81111	+0.05322	−9.75438	− 99.2 = 0	7	− 6.8
9	+0.28412	−8.74476	+9.57691	−0.55111	+0.36166	+7.38751	−171.3 = 0	6	−38.1
10	+0.25852	−8.02243	−7.16137	−0.52943	+0.22887	+0.24851	−156.3 = 0	7	−19.4
11	+0.23730	−8.59295	+9.16873	+0.52767	+0.22716	+0.43695	−149.6 = 0	7	−23.4
12	+0.21549	+8.34986	+9.38223	−0.27768	+0.11502	+0.43791	−136.1 = 0	14	− 7.6
13	+0.29100	+7.86688	+9.01305	+0.51485	+0.38880	+0.81577	−182.3 = 0	4	−14.8
14	+0.18405	+8.15168	+9.71458	−9.59125	+0.05323	+0.55416	−132.8 = 0	6	− 8.5
15	+0.27295	−7.35793	+9.88193	−9.92580	+0.41399	+0.98265	−148.3 = 0	9	+43.9
16	+0.17897	−8.15685	+9.78420	+9.99044	+0.05709	+0.68421	−130.9 = 0	6	− 0.5

Equations deduced from Declinations.

								Weights.	Residuals.
17	$-9{\cdot}78040 d\pi$	$-8{\cdot}75266 d\Omega$	$+0{\cdot}15678 di$	$-9{\cdot}87123 d\phi$	$-9{\cdot}68623 d\mathrm{M}$	$+0{\cdot}31021 dm$	$+ 13''{\cdot}3 = 0$	8	$-''{\cdot}7$
18	$+9{\cdot}19117$	$+9{\cdot}27321$	$-8{\cdot}86082$	$-9{\cdot}48705$	$+9{\cdot}18718$	$-9{\cdot}75395$	$+ 1{\cdot}1 = 0$	6	$+ 1{\cdot}7$
19	$-9{\cdot}61358$	$-9{\cdot}13893$	$+9{\cdot}99278$	$-9{\cdot}89734$	$-9{\cdot}59521$	$+0{\cdot}09315$	$+ 10{\cdot}2 = 0$	7	$- 2{\cdot}3$
20	$-9{\cdot}47516$	$+9{\cdot}16950$	$+9{\cdot}96204$	$+9{\cdot}55236$	$-9{\cdot}37565$	$+9{\cdot}80230$	$+ 14{\cdot}1 = 0$	5	$- 6{\cdot}6$
21	$+8{\cdot}79588$	$-9{\cdot}29232$	$-9{\cdot}60531$	$+9{\cdot}00368$	$+8{\cdot}90309$	$-9{\cdot}23117$	$- 9{\cdot}0 = 0$	10	$+ 0{\cdot}2$
22	$-9{\cdot}72061$	$+8{\cdot}90309$	$+0{\cdot}13658$	$+9{\cdot}23393$	$-9{\cdot}58985$	$+9{\cdot}79460$	$+ 28{\cdot}5 = 0$	7	$- 4{\cdot}7$
23	$+9{\cdot}84989$	$-8{\cdot}85576$	$-0{\cdot}26204$	$-9{\cdot}12743$	$+9{\cdot}99123$	$-0{\cdot}01796$	$- 45{\cdot}1 = 0$	12	$- 2{\cdot}8$
24	$-9{\cdot}78143$	$+7{\cdot}67302$	$+0{\cdot}18001$	$-9{\cdot}55128$	$-9{\cdot}65712$	$+9{\cdot}38550$	$+ 41{\cdot}7 = 0$	7	$+ 3{\cdot}9$
25	$+9{\cdot}76375$	$+9{\cdot}16388$	$-0{\cdot}09637$	$-0{\cdot}00231$	$+9{\cdot}82706$	$-8{\cdot}24674$	$- 46{\cdot}8 = 0$	6	$-11{\cdot}2$
26	$+8{\cdot}09899$	$+9{\cdot}26635$	$+9{\cdot}31587$	$-8{\cdot}46613$	$+8{\cdot}15866$	$+8{\cdot}24072$	$+ 6{\cdot}4 = 0$	8	$+ 1{\cdot}4$
27	$-9{\cdot}50410$	$-9{\cdot}19587$	$+9{\cdot}89020$	$-9{\cdot}80791$	$-9{\cdot}51124$	$-9{\cdot}71237$	$+ 21{\cdot}9 = 0$	7	$+ 2{\cdot}2$
28	$-9{\cdot}58222$	$+9{\cdot}12846$	$+0{\cdot}00985$	$+9{\cdot}70595$	$-9{\cdot}47026$	$-9{\cdot}79023$	$+ 40{\cdot}6 = 0$	13	$+ 5{\cdot}6$
29	$+9{\cdot}32354$	$-9{\cdot}24546$	$-9{\cdot}99666$	$+9{\cdot}40800$	$+9{\cdot}44806$	$+9{\cdot}86548$	$- 30{\cdot}2 = 0$	2	$- 5{\cdot}5$
30	$-9{\cdot}74129$	$+8{\cdot}80407$	$+0{\cdot}14985$	$+8{\cdot}75997$	$-9{\cdot}60795$	$-0{\cdot}10463$	$+ 53{\cdot}9 = 0$	6	$+ 6{\cdot}1$
31	$+9{\cdot}85477$	$-8{\cdot}35430$	$-0{\cdot}27305$	$-9{\cdot}77905$	$+9{\cdot}99333$	$+0{\cdot}55835$	$- 58{\cdot}4 = 0$	9	$+17{\cdot}2$
32	$-9{\cdot}77557$	$-8{\cdot}21696$	$+0{\cdot}17661$	$-9{\cdot}68365$	$-9{\cdot}65862$	$-0{\cdot}28239$	$+ 51{\cdot}5 = 0$	6	$- 0{\cdot}3$

Proceeding to solve these equations by the method of least squares, the normal equations are found to be—

$+399{\cdot}970d\pi$	$-2{\cdot}031d\Omega$	$+2{\cdot}594di$	$+2{\cdot}305d\phi$	$+411{\cdot}440d\mathrm{M}$	$+0{\cdot}801dm$	$-25985{\cdot}21=0$
$-2{\cdot}031$	$+1{\cdot}949$	$+3{\cdot}101$	$+0{\cdot}406$	$-1{\cdot}975$	$+0{\cdot}488$	$+193{\cdot}05=0$
$+2{\cdot}594$	$+3{\cdot}101$	$+208{\cdot}634$	$+6{\cdot}349$	$+2{\cdot}978$	$+6{\cdot}958$	$+30{\cdot}48=0$
$+2{\cdot}305$	$+0{\cdot}406$	$+6{\cdot}349$	$+716{\cdot}630$	$+15{\cdot}986$	$-207{\cdot}672$	$+2704{\cdot}66=0$
$+411{\cdot}440$	$-1{\cdot}975$	$+2{\cdot}978$	$+15{\cdot}986$	$+446{\cdot}794$	$+35{\cdot}835$	$-26969{\cdot}61=0$
$+0{\cdot}801$	$+0{\cdot}488$	$+6{\cdot}958$	$-207{\cdot}672$	$+35{\cdot}835$	$+2673{\cdot}042$	$-19641{\cdot}41=0$

whence the corrections to the assumed elements are—

$d\pi=$	$+63''{\cdot}994$	$di=$	$-0''{\cdot}655$	$d\mathrm{M}=$	$+0''{\cdot}789$
$d\Omega=$	$-31{\cdot}916$	$d\phi=$	$-1{\cdot}897$	$dm=$	$+7{\cdot}178$

The residuals given in the last column above have been formed by substituting these values in the equations of condition.

It is to be observed that in the equations of condition the coefficients are logarithms, whilst in the normal equations the coefficients are natural numbers.

The resulting mean elements of *Flora* are:—

Epoch of Mean Anomaly, 1876 August $24^{d}\cdot5$, Berlin M.T.

Mean anomaly, M	=	313°	21′	8″·64	
Long. of Perihelion, π	=	33	18	59·63	Mean Equinox and Ecliptic of 1876·0.
Long. of Node, Ω	=	110	38	47·24	
Inclination, i	=	5	53	0·71	
Angle of eccentricity, ϕ	=	9	0	54·39	

Mean daily motion of M, $\mu = 1086''\cdot338160$

Log. Semiaxis Major, $\log a =$ 0·3426944

After repeated trials it was found to be impossible to sensibly reduce the residuals by further correction of the elements. It was decided, therefore, to adopt the above mean elements, and to seek for the means of obtaining a better agreement between the observed and computed places of the planet by a modification of the values of the perturbations as given by Brünnow's Tables. The direct method of treatment would have been, of course, to compute the special perturbations for the normal epochs, starting from the osculating elements corresponding to the mean elements given above. But considering the laborious (and therefore costly) nature of the work of computing special perturbations for a period extending over twenty-three years, I did not feel justified in undertaking it at the present time. And as I had not sufficient leisure to undertake the more personally exacting work of examining the formation and integration of the perturbational equations, I decided to endeavour to obtain empirical corrections to the coefficients in Brünnow's expressions for the general perturbations. By this means I hoped, at all events, to be able to ascertain whether the residuals could be so far represented by reasonable changes in the values of these coefficients as to establish the substantial accuracy of the adopted elements.

The periodic expressions for the perturbations, due to the action of *Jupiter* and *Saturn* (the only planets taken into account by Brünnow), are of the form

$$\begin{matrix} a\cos \\ b\sin \end{matrix}\left(l\mathrm{M} + m\,\mathrm{4} + n\,\mathrm{h} \right)$$

where a and b are numerical quantities, M, 4, and h the mean anomalies respectively of *Flora*, *Jupiter*, and *Saturn*, and

l, m, and n whole numbers (positive or negative) or zero. After a good deal of trouble it was found that the following corrections (which, of course, are not to be considered as rigorously determined) to Brünnow's values of a and b, in various terms occurring in the perturbations of the true anomalies, would reduce the residuals to quantities that might be considered satisfactory, considering all the circumstances of the case:—

Argument.	Corrections to a	Corrections to b	Argument.	Corrections to a	Corrections to b
$M-4$	$+11''.6$	$+3''.1$	$2(2M-4)$	$-0''.5$	$-1''.2$
$2(M-4)$	$-7''.2$	$-1''.4$	M	$-2''.0$	$-0''.7$
$3(M-4)$	$-0''.7$	$+0''.8$	$M-3\,4$	$+7''.3$	$+2''.5$
-4	$+3''.5$	$-2''.1$	$3M-2\,4$	$-0''.6$	$+1''.6$
$2(-4)$	$+1''.0$	$-5''.9$	$3M-4\,4$	$-1''.6$	$-1''.5$
$3(-4)$	$-0''.8$	$+1''.3$	$-M-4$	$-1''.1$	$-0''.5$
$M-2\,4$	$-5''.4$	$-1''.3$	$-M-2\,4$	$+2''.1$	$+2''.0$
$2(M-2\,4)$	$-1''.5$	$-2''.1$	$M-4\,4$	$-2''.2$	$-3''.7$
$2M-3\,4$	$+4''.7$	$-0''.2$	$3M-4$	$-1''.4$	$+0''.3$
$2(2M-3\,4)$	$+1''.9$	$-6''.0$	$M-h$	$+0''.7$	$+0''.2$
$2M-4$	$+1''.9$	$-1''.0$			

It was not considered worth while proceeding with this part of the investigation farther, so as to obtain the corresponding corrections to the perturbations of the radius vector and of the coordinate z.

The above corrections were, therefore, applied to the perturbations of the true anomalies taken from the Tables (the other perturbations remaining unchanged), and geocentric places of *Flora* computed by their means, from the corrected elements, for the normal epochs.

These places were compared with "observed" places, obtained by applying the adopted errors of the Tables, given at the beginning of this paper, to the *Berliner Jahrbuch* places for the various dates. Thus the following errors of computed places were obtained:—

No.	Berlin Mean Time.	$\Delta\alpha$	$\Delta\alpha \cos\delta$	$\Delta\delta$
	d	s	″	″
1	1865 Mar. 21·5	+0·24	+3·5	−2·3
2	1866 July 11·5	+0·19	+2·7	+0·7
3	1868 Feb. 22·5	−0·15	−2·1	+0·7
4	1869 June 8·5	−0·08	−1·1	−1·9
5	1870 Dec. 29·5	0·00	0·0	−2·9
6	1872 May 15·5	+0·17	+2·5	−4·0
7	1873 Nov. 8·5	+0·55	+8·2	+5·5
8	1875 April 17·5	0·00	0·0	−0·1
9	1876 Aug. 24·5	−0·45	−6·4	−0·3
10	1879 July 5·5	−0·36	−5·0	−0·1
11	1881 Feb. 13·5	+0·11	+1·5	−4·1
12	1882 June 9·5	+0·17	+2·5	+2·4
13	1883 Dec. 4·5	+0·31	+4·4	−3·9
14	1885 May 12·5	+0·03	+0·4	+1·7
15	1886 Oct. 29·5	+0·02	+0·3	+2·6
16	1888 April 12·5	−0·11	−1·6	−4·6

There is an *erratum* in the declination of *Flora* for 1869 June 8, as given in the *Berliner Jahrbuch* for 1871, where −17° 27′ 16″·5 should read −17° 27′ 46″·5.

For the convenience of astronomers who may wish to use the corrected elements of *Flora*, in combination with Brünnow's Tables, for the purpose of computing an Ephemeris, I append here continuations or modifications of certain of the Tables, or of parts of them, by means of which the necessary computations can be made with facility for the period 1892–1900.

My thanks are due to the Government Grant Committee of the Royal Society for a grant to defray the expenses of the computations connected with this investigation.

Continuation of Brünnow's Tafel I., "Argumente für die Jahre."

		I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.
B.	1892	222·59	17·12	239·71	102·30	68·07	205·5	256·8	290·7	324·9	171·6	188·8	273·9	273·5	205·9
	1893	302·41	346·80	289·20	231·61	258·03	315·6	275·9	200·5	174·0	31·1	18·0	262·8	213·6	4·8
	1894	22·23	315·47	338·70	0·92	87·99	65·8	295·1	110·2	23·1	250·6	207·2	251·6	153·7	163·7
	1895	102·04	286·15	25·19	130·23	277·95	175·9	314·3	20·0	232·3	110·2	36·4	240·5	93·8	322·6
B.	1896	182·08	255·74	77·82	259·90	108·43	286·4	333·5	290·6	81·9	329·4	225·2	229·3	34·7	120·8
	1897	261·90	225·41	127·31	29·21	298·39	36·5	352·7	200·4	291·0	188·9	54·4	218·2	334·9	279·7
	1898	341·72	195·09	176·80	158·52	128·35	146·6	11·9	110·1	140·2	48·5	243·6	207·0	275·0	78·6
	1899	61·54	164·77	226·30	287·83	318·31	256·8	31·0	19·9	349·3	268·0	72·8	195·9	215·1	237·5
	1900	141.35	134·44	275·79	57·14	148·27	6·9	50·2	289·6	198·5	127·5	262·0	184·7	155·2	36·4

		XV.	XVI.	XVII.	XVIII.	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.	XXVIII.
B.	1892	153·2	15·8	187·5	342·0	119·0	358·7	128·3	282·8	51·1	334·0	179·5	333·8	77·4	102·1
	1893	142·8	85·2	116·5	160·8	169·2	98·4	226·3	270·6	136·8	47·5	3·1	181·9	315·0	48·1
	1894	132·4	154·7	45·4	339·6	219·5	198·2	324·2	258·4	222·5	121·0	186·8	30·0	192·7	354·1
	1895	122·0	224·1	334·4	158·4	269·7	297·9	62·2	246·2	308·2	194·5	10·4	238·1	70·3	300·1
B.	1896	112·6	294·6	264·2	337·7	321·0	39·0	160·3	233·9	34·3	268·3	194·6	86·6	307·5	247·0
	1897	102·2	4·0	193·1	156·5	11·3	138·7	258·3	221·7	120·0	341·8	18·2	294·7	185·2	193·0
	1898	91·8	73·5	122·1	335·3	61·5	238·4	356·2	209·5	205·7	55·3	201·9	142·8	62·8	139·0
	1899	81·4	142·9	51·0	154·1	111·8	338·2	94·1	197·3	291·4	128·8	25·5	350·9	300·5	85·0
	1900	71·0	212·3	339·9	332·9	162·1	77·9	192·0	185·1	17·1	202·3	209·2	199·0	178·2	31·0

In the formation of these arguments the mean anomalies of *Flora* have been computed from the corrected elements. The mean anomalies of *Jupiter* and *Saturn* have been taken from Le Verrier's Tables, and are corrected for the Great Inequality.

Table to be substituted for the First Part (page 6) of Brünnow's Tafel IV., "Für die mittlere Anomalie."

	M	t
	° ′ ″	
B. 1892	205 28 29·89	+44·000
1893	315 37 3·32	+44·999
1894	65 45 36·75	+45·999
1895	175 54 10·18	+46·998
B. 1896	286 20 49·94	+48·000
1897	36 29 23·37	+48·999
1898	146 37 56·80	+49·999
1899	256 46 30·23	+50·998
1900	6 55 3·66	+51·997

	M	t
	° ′ ″	
January	0 0 0·00	+0·000
February	9 21 16·48	+0·085
March	17 48 13·95	+0·162
April	27 9 30·43	+0·246
May	36 12 40·58	+0·329
June	45 33 57·06	+0·413
July	54 37 7·21	+0·496
August	63 58 23·69	+0·580
September	73 19 40·17	+0·665
October	82 22 50·32	+0·747
November	91 44 6·80	+0·832
December	100 47 16·95	+0·915

Days.	M	t
	° ′ ″	
1	0 18 6·34	+0·003
2	0 36 12·68	+0·005
3	0 54 19·01	+0·008
4	1 12 25·35	+0·011
5	1 30 31·69	+0·014
6	1 48 38·03	+0·016
7	2 6 44·37	+0·019
8	2 24 50·71	+0·022
9	2 42 57·04	+0·025
10	3 1 3·38	+0·027
20	6 2 6·76	+0·055
30	9 3 10·14	+0·082

In bissextile years (marked B above) subtract one day from the date during January and February.

Corrections to Brünnow's Tafel V., "Für die Mittelpunkts-Gleichung," and Tafel VI., "Für den elliptischen Radius Vector."

M	Δ(*v*−M).	Δ log. *r*.	M	Δ(*v*−M).	Δ log *r*.
°	″		°	″	
0	0·00	+27	90	−3·50	−29
1	−0·06	+27	95	−3·42	−32
5	−0·49	+26	100	−3·33	−34
10	−0·97	+25	105	−3·17	−37
15	−1·42	+23	110	−2·97	−40
20	−1·85	+21	115	−2·77	−40
25	−2·24	+18	120	−2·57	−40
30	−2·59	+15	125	−2·37	−41
35	−2·89	+11	130	−2·17	−43
40	−3·15	+ 7	135	−1·96	−46
45	−3·38	+ 3	140	−1·75	−49
50	−3·60	− 2	145	−1·54	−49
55	−3·70	− 5	150	−1·33	−49
60	−3·73	− 8	155	−1·12	−49
65	−3·74	−11	160	−0·91	−50
70	−3·75	−15	165	−0·70	−50
75	−3·69	−20	170	−0·48	−50
80	−3·63	−24	175	−0·25	−51
85	−3·57	−26	180	0·00	−51

These corrections reduce the Equation of the Centre and the log radius vector, taken from Brünnow's Tables, to the corresponding values deduced from the corrected elements.

The corrections for intermediate values of M can be found, with sufficient accuracy, by interpolation.

When M is greater than 180° the argument is 360°−M. In this case the sign of Δ (*v*−M) must be changed, but the sign of Δ log *r* remains unchanged.

The values of Δ log *r* are expressed in units of the seventh decimal.

Continuation of Brünnow's Tafel XIV., "Für die Constanten in Bezug auf den Aequator."

	A	B	C	log *a*	log *b*	log *c*	log cos *a*	log cos *b*	log cos *c*
1892	123° 28′ 40″·36	35° 37′ 20″·07	19° 42′ 44″·98	9·9979988	9·9694194	9·5738927	8·98127	9·55923*n*	9·96711
1893	123 29 30·75	35 38 9·19	19 43 36·69	9·9979992	9·9694233	9·5738660	8·98123	9·55921*n*	9·96711
1894	123 30 21·15	35 38 58·31	19 44 28·41	9·9979996	9·9694271	9·5738394	8·98119	9·55918*n*	9·96712
1895	123 31 11·55	35 39 47·44	19 45 20·13	9·9980000	9·9694310	9·5738127	8·98115	9·55916*n*	9·96712
1896	123 32 2·09	35 40 36·70	19 46 11·99	9·9980004	9·9694349	9·5737860	8·98110	9·55913*n*	9·96713
1897	123 32 52·48	35 41 25·82	19 47 3·72	9·9980008	9·9694387	9·5737594	8·98106	9·55911*n*	9·96713
1898	123 33 42·88	35 42 14·94	19 47 55·45	9·9980012	9·9694426	9·5737327	8·98102	9·55908*n*	9·96714
1899	123 34 33·28	35 43 4·07	19 48 47·18	9·9980016	9·9694464	9·5737061	8·98098	9·55906*n*	9·96714
1900	123 35 23·68	35 43 53·20	19 49 38·90	9·9980020	9·9694503	9·5736794	8·98093	9·55903*n*	9·96715

These quantities have been computed from the corrected elements, and the values of A, B, and C modified by subtraction of a constant (9′ 46″·5) from each, so as to be applicable to the perturbed true anomalies, when the perturbations are taken from Brünnow's Tables.

Nautical Almanac Office:
1892 *July* 26.

Greenwich Mean Times of Superior and Inferior Geocentric Conjunctions of Jupiter's Fourth Satellite (Callisto) from 1892 *November to the end of* 1893.

(*Communicated by the Superintendent of the "Nautical Almanac."*)

Attention having been drawn to the matter by Mr. Freeman in the current number of the *Observatory*, the following times of geocentric conjunctions of what has hitherto been known as *Jupiter's* Fourth Satellite are communicated to the Society, in the hope that they may be useful to observers generally.

The conjunctions of which the times are here given are geocentric conjunctions with the centre of the planet in the plane of the orbit of the satellite.

Superior Conjunctions.

1892.	d	h	m	1893.	d	h	m
Nov.	3	10	18·5	June	9	20	6·5
	20	1	13·0		26	16	37·0
Dec.	6	17	5·8	July	13	12	43·3
	23	10	3·1		30	8	17·0
1893. Jan.	9	4	2·1	Aug.	16	3	9·1
	25	22	55·6	Sept.	1	21	11·9
Feb.	11	18	33·8		18	14	16·2
	28	14	45·7	Oct.	5	6	18·5
Mar.	17	11	22·1		21	21	22·7
Apr.	3	8	15·3	Nov.	7	11	42·2
	20	5	16·5		24	1	43·6
May	7	2	19·5	Dec.	10	15	58·2
	23	23	18·7		27	6	53·1

Inferior Conjunctions.

1892.	d	h	m	1893.	d	h	m
Nov.	11	19	32·2	June	18	7	55·9
	28	10	56·4	July	5	4	12·5
Dec.	15	3	20·4		22	0	0·6
	31	20	47·5	Aug.	7	19	12·4
1893. Jan.	17	15	13·5		24	13	37·9
Feb.	3	10	28·1	Sept.	10	7	9·5
	20	6	22·0		26	23	41·5
Mar.	9	2	45·5	Oct.	13	15	12·7
	25	23	28 9		30	5	52·5
Apr.	11	20	24·7	Nov.	15	20	1·4
	28	17	26·3	Dec.	2	10	7·3
May	15	14	25·6		19	0	39·8
June	1	11	17·4	1894. Jan.	4	16	2·4

Nautical Almanac Office:
1892 *October* 5.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Year 1891.

By John Tebbutt.

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m	Mean Time of *Nautical Almanac.* h m s
Aug. 20	III.	Tr. Egr.	Int. contact	8-inch	95	0 53 1	
20	III.	,,	Bisection	,,	,,	0 57 6	1 2
20	III.	,,	Ext. contact	,,	,,	1 1 20	
Sept. 2	II.	Ecl. D.	Last seen	,,	170	23 59 53	23 59 39
3	I.	Tr. Egr.	Int. contact	,,	,,	0 32 8	
3	I.	,,	Bisection	,,	,,	0 33 38	0 35
3	I.	,,	Ext. contact	,,	,,	0 34 57	
10		Occ. D.	First contact	$4\frac{1}{2}$-inch	120	21 14 18	
10	I.	,,	Bisection	,,	,,	21 16 47	21 16
10	I.	Ecl. R.	First seen	8-inch	170	23 41 1	23 40 58
11	I.	Tr. Egr.	Bisection	$4\frac{1}{2}$-inch	180	20 42 33	
11	I.	,,	Ext. contact	,,	,,	20 45 3	20 44
11	Shd. I.	,,	Int. contact	,,	,,	20 50 12	
11	Shd. I.	,,	Bisection	,,	,,	20 52 12	20 55
11	Shd. I.	,,	Ext. contact	,,	,,	20 52 57	

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of *Nautical Almanac.* h m s
Sept. 11	II.	Tr. Ingr.	Ext. contact	4½-inch	180	21 1 15	
11	II.	,,	Bisection	,,	,,	21 4 5	21 4
11	II.	,,	Int. contact	,,	,,	21 5 40	
11	II.	Tr. Egr.	Int. contact	,,	120	23 50 52	
11	II.	,,	Bisection	,,	,,	23 51 42	23 55
11	II.	,,	Ext. contact	,,	,,	23 55 1	
18	I.	,,	Int. contact	8-inch	170	22 22 33	
18	I.	,,	Bisection	,,	,,	22 25 22	22 28
18	I.	,,	Ext. contact	,,	,,	22 27 32	
18	II.	Tr. Ingr.	Ext. contact	,,	,,	23 15 39	
18	II.	,,	Bisection	,,	,,	23 18 28	23 21
18	II.	,,	Int. contact	,,	,,	23 20 48	
20	II.	Ecl. R.	First seen	,,	,,	21 14 46	21 14 3
20	II.	,,	Full brightness	,,	,,	21 16 46	
27	II.	,,	First seen	,,	,,	23 49 31	23 49 40
27	II.	,,	Full brightness	,,	,,	23 52 9	
Oct. 1	III.	Tr. Egr.	Int. contact	,,	230	20 40 45	
1	III.	,,	Bisection	,,	,,	20 44 15	20 48
1	III.	,,	Ext. contact	,,	,,	20 48 44	

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of *Nautical Almanac.* h m s
Oct. 3	I.	Ecl. R.	First seen	8-inch	230	23 55 41	23 55 41
3	I.	,,	Full brightness	,,	,,	23 58 0	
4	I.	Tr. Egr.	Int. contact	,,	,,	20 19 42	20 24
4	I.	,,	Bisection	,,	,,	20 22 17	
4	I.	,,	Ext. contact	,,	,,	20 24 21	
4	II.	Occ. D.	First contact	,,	,,	22 9 14	22 10
4	II.	,,	Bisection	,,	,,	22 11 23	
4	II.	,,	Last seen	,,	,,	22 13 3	
8	III.	Tr. Ingr.	Ext. contact	,,	130	20 51 11	20 49
8	III.	,,	Bisection	,,	,,	20 55 20	
8	III.	,,	Int. contact	,,	,,	20 59 14	
9	III.	Tr. Egr.	Int. contact	,,	110	0 5 3	0 13
9	III.	,,	Bisection	,,	130	0 8 33	
9	III.	,,	Ext. contact	,,	,,	0 13 32	
9	Shd. III.	Tr. Ingr.	Int. contact	,,	,,	0 14 32	0 6
10	I.	Occ. D.	First contact	,,	170	22 43 14	22 44
10	I.	,,	Bisection	,,	,,	22 45 29	
10	I.	,,	Last seen	,,	,,	22 46 18	

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of *Nautical Almanac* h m s
Oct. 11	I.	Tr. Egr.	Int. contact	8-inch	170	22 7 6	
11	I.	,,	Bisection	,,	,,	22 8 56	22 11
11	I.	,,	Ext. contact	,,	,,	22 10 55	
12	I.	Ecl. R.	First seen	,,	,,	20 19 56	
12	I.	,,	Full brightness	,,	,,	20 21 44	20 19 57
14	IV.	Occ. R.	Bisection	,,	,,	21 20 5	
14	IV.	,,	Last contact	,,	,,	21 22 49	21 28
18	I.	Tr. Ingr.	Ext. contact	,,	,,	21 39 47	
18	I.	,,	Bisection	,,	,,	21 41 37	21 40
18	I.	,,	Int. contact	,,	,,	21 43 51	
29	II.	Ecl. R.	First seen	,,	130	23 32 55	
29	II.	,,	Full brightness	,,	,,	23 35 55	23 32 34
Nov. 1	IV.	,,	First seen	,,	...	0 5 44	
1	IV.	,,	Full brightness	,,	...	0 16 28	0 9 30
2	III	Occ. D.	First contact	,,	...	21 16 27	
2	III.	,,	Bisection	,,	...	21 18 37	21 17
2	III.	,,	Last seen	,,	...	21 21 6	

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of *Nautical Almanac*. h m s
Nov. 2	I.	Occ. D.	First contact	8-inch	130	22 34 14	
2	I.	,,	Bisection	,,	...	22 37 29	22 38
2	I.	,,	Last seen	,,	...	22 39 43	
14	II.	Tr. Egr.	Int. contact	,,	200	21 18 0	
14	II.	,,	Bisection	,,	,,	21 20 15	21 24
14	II.	,,	Ext. contact	,,	,,	21 22 29	
25	I.	Occ. D.	First contact	$4\frac{1}{2}$-inch	300	22 45 21	
25	I.	,,	Bisection	,,	,,	22 47 6	22 46
25	I.	,,	Last seen	,,	,,	22 48 26	
Dec. 16	II.	Tr. Egr.	Bisection	8-inch	130	21 12 38	21 11
16	II.	,,	Ext. contact	,,	,,	21 14 58	
19	I.	,,	Int. contact	$4\frac{1}{2}$-inch	180	22 29 16	
19	I.	,,	Bisection	,,	,,	22 31 16	22 32
19	I.	,,	Ext. contact	,,	,,	22 33 36	
27	I.	Ecl. R.	First seen	,,	90	23 3 27	23 2 41
27	I.	,,	Full brightness	,,	,,	23 5 14	

Remarks.

Aug. 20.—Fair definition.

Sept. 2.—Good definition. Satellite appeared as a narrow band of light parallel to the planet's limb.

Sept. 3.—Excellent definition; internal contact noted rather late.

Sept. 10.—Planet's limb boiled violently after the bisection. Sky beautifully clear at the reappearance, and the satellites perfectly tranquil circular discs. These measures with the filar micrometer, which were very consistent, gave 47″·57 as the polar diameter of the planet.

Sept. 11.—Satellite I. fairly defined, but there was a slight boiling at the egress of the shadow. Definition bad at ingress, but good at egress, of II.

Sept. 18.—Good definition throughout for I., and for first two phases of II. Images tremulous at internal contact of II.

Sept. 20.—Images steady and well defined, but seen through thin cloud.

Sept. 27.—The three satellites on the west side of the planet were circular, tranquil discs, but that next to the planet was very hazy and indistinct as compared with the brilliancy of the others.

Oct. 1.—Images steady and pretty well defined, but III. unusually faint at internal contact, and appeared oval along the limb.

Oct. 3.—Sky clear and Moon absent; definition pretty good.

Oct. 4.—Definition of I. pretty good and of II. excellent. Observations unusually good.

Oct. 8, 9.—Definition good throughout.

Oct. 10.—Definition pretty good at first contact, but bad at the two other phases.

Oct. 11.—Images very steady and beautifully defined. Observations made with unusual precision.

Oct. 12.—Clear sky, and strong twilight; images fairly defined, but rather tremulous.

Oct. 14.—Satellite faint and slightly dusky.

Oct. 18.—Images tremulous.

Oct. 29.—Sky clear, and steadiness and definition satisfactory.

Nov. 1.—Sky clear and definition good. During the reappearance the planet was occulted by one of the bars of the square micrometer. The recovery of light was so excessively slow that it was impossible to fix the time of full brightness with any approach to accuracy.

Nov. 2.—Images steady and well defined.

Nov. 14.—Excellent definition; internal contact noted late.

Nov. 25.—Definition pretty good, and sky hazy.

Dec. 16.—Images tremulous, and badly defined in strong twilight.

Dec. 19.—Sky beautifully clear, but definition bad.

Dec. 27.—Definition pretty good. Sky free from cloud, but slightly hazy from smoke.

Note.—With the exception of Nov. 1 an occulting bar was not employed in the observations of the eclipses for 1891. The times given in the first and seventh columns are the Windsor mean times of observation diminished by $10^h\ 3^m\ 20{\cdot}5^s$, and entered to the nearest second.

Private Observatory, Windsor, N. S. Wales.
1892 *June* 5.

Observations of U Orionis. By Lieutenant-Col. E. E. Markwick.

The following are my observations of the above star in 1892, made with a binocular magnifying five times:—

		m				m
Jan.	1	9	Just glimpsed.	1892 Feb.	1	6·37
	3	8·65			23	6·57
	5	8·2	Visible in moonlight.		24	6·57
	6	7·6			25	6·4
	21	6·27			26	6·8
	24	6·32		Mar.	22	7·9
	25	6·27			28	8·3
	27	6·32			30	8·8
	29	6·37				

The magnitudes are on the H.P. scale as nearly as may be. The maximum appears to have occurred about January 23; but the change of brightness of this star about this period is so slow that it is somewhat difficult to allocate the maximum with certainty. Assuming it to have been at maximum on December 13, 1885, when first discovered by Gore, we have an interval of 2,232 days to January 23 this year, during which six periods elapsed. Hence the mean period would be 372 days. As, however, this is perhaps rather a hazardous assumption, let us take 1886 December 12 as a well-determined maximum. This is the mean of four observers—viz. Gore, December 11; Markwick, December 16; Sawyer, December 13; and Parkhurst, December 9. From 1886 December 12 to 1892 January 23 is 1,868 days, or five periods, which will give the mean as 373·6 days. This last is identical with the first value given by Gore on p. 518, vol. l., of the *Monthly Notices*, and also only differs from his provisional value (373·47 days) by 0·13 day. This is, of course, on the assumption that all these periods are identical in length. If, as Chandler supposes, there is some slow, gradual lengthening or dwindling of the period by a periodic term, then a very much longer series of observations will have to be obtained before this can be definitely ascertained.

Haulbowline, Queenstown:
1892 *September.*

Observations of Swift's Comet (a 1892) and Winnecke's Periodic Comet, made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks, equatoreal, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

The observations are corrected for refraction, but not for parallax.

Swift's Comet (a 1892).

Greenwich Mean Solar Time.	Observer.	☄−★R.A.	Corr. for Refraction.	Log factor of Parallax.	☄−★N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Appt. R.A. of ☄	Appt N.P.D. of ☄	Comp. Star.
1892. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
June 9 14 14 41	B.	+3 33·05	0·00	9·6573	−10 59·1	−0·1	0·5989	2	0 11 27·13	49 22 50·5	*a*
9 14 14 41	,,	+2 32·50	0·00	9·6573	−11 23·1	−0·1	0·5989	2	0 11 27·28	49 22 54·1	*b*
27 11 2 23	A.C.	+0 12·60	0·00	9·6998	+ 0 38·8	0·0	0·7817	3	0 41 4·54	44 14 19·8	*c*
30 10 30 51	,,	−0 2·50	−0·04	9·6888	−20 14·1	−1·1	0·8045	4	...	...	*d*
30 10 33 6	,,	−1 55·00	0·00	9·6907	+ 2 17·9	+0·2	0·8020	3	...	...	*e*

Winnecke's Comet.

1892. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
June 27 10 35 7	A.C.	−0 21·73	−0·13	9·5979	+11 48·9	+1·9	0·8544	2	9 6 22·72	54 38 42·7	*f*

Comparison Stars.

	Star's Name.	Mean R.A., 1892·0.	Mean N.P.D., 1892·0.	Authority.
		h m s	° ′ ″	
a	23 Andromedæ	0 7 54·18	49 33 39·7	Greenwich Observations, 1888 and 1889.
b	Piazzi O., 13	0 8 54·88	49 34 7·3	Greenwich Observations, 1887 and 1888.
c	O.A. (N.) 728	0 40 51·62	44 13 33·3	Second Armagh Catalogue, 1875, and Paris Catalogue, 1882.
d	B.D. +45°, 215	0 44 56·5	43 52	Bonn Observations, vol. v.
e	B.D. +46°, 189	0 46 51·8	43 28	„ „ „
f	W.B. (2) IX., 70, 71, 72	9 6 44·67	54 27 0·7	Weisse's Bessel, vol. ii.

Notes.

Star *f* is a close triple star, the components being nearly equal. The mean of their places has been used, as the triplicity was not noticed with the low power employed. Winnecke's comet was very bright on June 27, and was readily visible in spite of the bright twilight.

The following meridian observations of Swift's comet were made with the Transit Circle :—

Greenwich Mean Solar Time.	Observer.	R.A.	N.P.D. (Corrected for Refraction and Parallax.)
1892. d h m s		h m s	° ′ ″
Aug. 30 14 4 47	A.C.	0 43 39·37	37 14 9·80
Sept. 3 13 44 11	„	0 38 45·83	37 32 12·73

In computing the parallax log Δ was taken as 0·2676 on August 30, 0·2700 on September 3, these values being interpolated from Archenhold's Ephemeris.

The initials A.C. and B. are those of Mr. Crommelin and Mr. Bryant respectively.

Sextant Observations of Swift's Comet made on board the Ship "Eaton Hall." By Capt. G. M. Lourison.

(*Communicated by the Secretaries.*)

1892 April 6, position at noon, lat. 17° 30′ S., long. 27° 53′ W. 4 A.M., moderate E. to E. by N. breezes and clear sky. 5 A.M., altitude of comet 42° 40′ 47″; G.M.T., 19^h 1^m 24^s. Distance from *Vega*, 53° 8′ 0″; *Mars*, 34° 52′ 0″; *α Centauri*, 91° 18′ 0″. Noon, brisk E. to E. by N. winds and clear sky. At 5 A.M., while observing the comet, a brilliant meteor shot from under it, illuminating the whole sky, and leaving a train of light which lasted a full minute and a half. The tail of the meteor was spiral as it fell.

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